DIESEL EXHAUST

Diesel exhaust is currently in the identification phase as a proposed Toxic Air Contaminant under California's air toxics program (AB 1807). A draft document published in May, 1997 is available.

CAS Registry Number: N/A

Molecular Formula: N/A

Diesel exhaust is a complex mixture of gases, vapors, and fine particles. Some of the exhaust components, like arsenic, benzene and nickel, are known to cause cancer in humans. At least 40 other components, including suspected human carcinogens benzo[a]pyrene, 1,3-butadiene and formaldehyde, are listed by the United States Environmental Protection Agency (U.S. EPA) as hazardous air pollutants and the Air Resources Board (ARB) as toxic air contaminants (see Table 1). Diesel Exhaust also contains carbon monoxide, oxides of nitrogen, sulfur dioxide, hydrocarbons, particulate matter (PM), aldehydes, ketones, sulfates, cyanides, phenols, ammonia, and metals. Some of these substances can result from unburned fuel and lubricating oil components, products of incomplete combustion, or a result of engine wear or trace contaminants (Volkswagen, 1989).

In this substance review, California's population exposure to diesel exhaust PM is discussed in more detail because more is known about the PM fraction, and most researchers believe that the diesel exhaust particles contribute the majority of the risk from exposures to diesel exhaust.

Diesel exhaust particles carry many of the harmful organics and metals present in the exhaust. Typical diesel exhaust particles have mass-median aerodynamic diameters ranging from 0.1 to 0.25 micrometers (μm) (Groblicki and Begeman, 1979; Dolan et al., 1980; NRC, 1982; Williams, 1982). More than 75 percent of the particles are smaller than 1 μm (Pierson et al., 1983) and are mainly aggregates of spherical elemental carbon particles coated with organic and inorganic substances. The particles have a sponge-like structure and large surface area which attracts compounds of low volatility to the inside or surface of the particles. The primary organic compounds associated with the particles include aliphatic hydrocarbons, polycyclic aromatic hydrocarbons (PAH), and PAH-derivatives (Zielinska, 1990). Methylated PAHs appear to be the most abundant PAH derivatives and more than 50 nitro-PAHs have been identified in diesel exhaust (ARB, 1997d).

TABLE 1 - TOXIC AIR CONTAMINANTS FOUND IN DIESEL EXHAUST*

acetaldehyde	chlorine	methyl ethyl ketone
acrolein	chlorobenzene	naphthalene
aluminum	chromium compounds	nickel
ammonia	cobalt compounds	4-nitrobiphenyl
aniline	copper	phenol
antimony compounds	cresol	phosphorus
arsenic	cyanide compounds	**POM (including PAHs)
barium	dibenzofuran	propionaldehyde
benzene	dibutylphthalate	selenium compounds
beryllium compounds	ethyl benzene	silver
biphenyl	formaldehyde	styrene
bis [2-ethylhexyl]phthalate	hexane	sulfuric acid
bromine	lead compounds	toluene
1,3-butadiene	manganese compounds	xylene isomers and mixtures
cadmium	mercury compounds	zinc
chlorinated dioxins	methanol	

(ARB, 1997d)

* This list of toxic air contaminants have either been identified in diesel exhaust, or presumed to be in the exhaust based on observed chemical reactions and/or presence in the fuel or oil.

** See Polycyclic Organic Matter (POM) Fact Sheet.

SOURCES AND EMISSIONS

A. Sources

Diesel exhaust PM emissions can be emitted from mobile sources (on-road vehicles and off-road mobile sources), stationary area sources, and stationary point sources. On-road diesel vehicles contribute approximately 59 percent of California's diesel exhaust PM. Other mobile sources contribute about 36 percent, and stationary area and point sources contribute the remaining amount. Stationary area sources of diesel exhaust include shipyards, warehouses, heavy equipment repair yards, and oil and gas production operations where exhaust emissions result from multiple locations within the site (ARB, 1997d). The primary stationary sources that have reported emissions of diesel exhaust are heavy construction (except highway), electrical services, and crude petroleum and natural gas extraction (ARB, 1997b).

B. Emissions

The total emissions of diesel exhaust from stationary sources in California are estimated to be at least 31,000 pounds per year, based on data reported under the Air Toxics “Hot Spots” Program (AB 2588) (ARB, 1997b). Also, based on the ARB 1990 emissions inventory, approximately 58,000 tons of diesel exhaust PM_{10} from all sources are emitted into California air each year (ARB, 1997d).

Emissions from on-road mobile source diesel exhaust PM_{10} in California are expected to decline by approximately 50 percent from 1990 until about 2010 as a result of mobile source standards and regulations already adopted by the ARB through 1996. The expected reduction is mainly due to adopted diesel vehicle emission and fuel regulations, even though both the number and vehicle miles traveled (VMT) of heavy-duty trucks are expected to increase during this period. Similarly, NO_x emissions from on-road diesel vehicles have been reduced since 1990, and will continue to be reduced through 2010 because of new NO_x engine emission standards (ARB, 1997d).

C. Natural Occurrence

Diesel exhaust is a product of diesel fuel combustion and does not occur naturally in the environment.

AMBIENT CONCENTRATIONS

The ARB has conducted a preliminary estimation of diesel exhaust concentrations for California's 15 air basins using a PM-based exposure method. This method used the ARB emissions inventory's database for particulate matter 10 microns or smaller (PM_{10}); ambient PM_{10} monitoring network data; and the results from several studies where chemical speciation of ambient data was performed, along with receptor modeling techniques to estimate statewide outdoor concentrations of diesel exhaust PM_{10}. The statewide population-weighted average diesel exhaust PM concentration is estimated to be 3.2 micrograms per cubic meter ($\mu g/m^3$). The basin-wide average diesel exhaust PM estimates ranged from 0.3 (in the Great Basin Valley) to 3.6 $\mu g/m^3$ (in the South Coast Air Basin) (ARB, 1997d).

INDOOR SOURCES AND CONCENTRATIONS

To estimate Californians' exposures to diesel exhaust particles, ARB staff used estimates of population-weighted ambient diesel exhaust particle concentrations in a model that can estimate indoor air concentrations, population indoor air exposure, and total air exposure. The model, called the California Population Indoor Exposure Model (CPIEM), was recently developed under contract to the ARB to improve estimates of population exposures to toxic air pollutants. The model uses relevant data (such as distributions of California building air exchange rates, activity patterns data, and air concentrations of diesel exhaust particles) as inputs to develop indoor concentration estimates across all environments.

The average indoor exhaust particle concentrations estimated by the model ranged from 1.7 $\mu g/m^3$, in office buildings to 3.2 $\mu g/m^3$ in industrial plants and inside vehicles. These estimates were combined with activity pattern data in the model to estimate Californians' exposures across all enclosed environments. The exposure modeling results indicate that Californians were exposed to average diesel exhaust particle concentrations of 2.1 $\mu g/m^3$ in enclosed environments in 1990. This is two-thirds of the population-weighted ambient average outdoor diesel exhaust PM_{10} concentration (ARB, 1997d).

ATMOSPHERIC PERSISTENCE

Physical removal of diesel exhaust PM from the atmosphere is usually accomplished through accretion of the particles, atmospheric fall-out (dry deposition), and atmospheric removal by rain (wet deposition). The particles, generally smaller than 1 μm, are expected to remain in the atmosphere from 5 to 15 days (Pierson et al., 1983; Balkanski et al., 1993).

AB 2588 RISK ASSESSMENT INFORMATION

Although diesel exhaust is reported as being emitted in California from stationary sources, no health values (cancer or non-cancer) are listed in the California Air Pollution Control Officers Association Air Toxics "Hot Spots" Program Revised 1992 Risk Assessment Guidelines for use in risk assessments (CAPCOA, 1993).

HEALTH EFFECTS

The probable route of human exposure to diesel exhaust is inhalation (ARB, 1994b).

Non-Cancer: Non-cancer effects of diesel exhaust are likely due to the presence of particles in the exhaust (WHO, 1994). A Recent study has reported that exposures to airborne respirable particulate matter are associated with increased morbidity and mortality, with observed effects including respiratory symptoms, changes in lung function, and increased hospitalizations for respiratory and cardiovascular disease (Pope et al., 1995a). Cellular changes upon exposure to particles include an accumulation of particle-laden macrophages and proliferation of bronchiolar epithelium of type II alveolar cells. Studies by Ulfvarson and coworkers (in 1990 and 1991) showed pulmonary function increases after a workshift during which diesel exhaust was removed from the work environment (Ulfvarson et al., 1990; 1991).

In June of 1993, the U.S. EPA determined an inhalation Reference Concentration (RfC) of 5 $\mu g/m^3$ for non-cancer effects of diesel exhaust. The U.S. EPA estimates that inhalation of this concentration or less, over a lifetime, would not likely result in the occurrence of chronic non-cancer effects (ARB, 1997d).

The available literature does not provide sufficient information to determine whether or not diesel exhaust exposure induces reproductive, developmental or teratogenic effects in humans. Exposure via inhalation did not induce sperm abnormalities nor affect spermatogonial survival in mice and monkeys though sperm anomalies have been observed in hamsters. Data on the effects of diesel exhaust on female reproductive capacity are limited, but potential effects on the corpora lutea and mating period have been suggested for laboratory rodents. Rats born to dams exposed to high concentrations of diesel exhaust had delayed ossification of the chest. Exposure during the neonatal developmental period of rodents induces neurobehavioral and neurophysiological effects, but does not affect general lung development. Generational studies conducted in rodents revealed that inhalation exposure to diesel exhaust resulted in increases in lung weight in all generations examined (ARB 1997d).

Cancer: Epidemiological studies in truck drivers, transport and equipment workers, dock workers, and railway workers, reported a statistically significant increase in the incidence of lung cancer associated with exposure to diesel exhaust. Two studies reported no category with a risk ratio elevated for exposure to diesel exhaust (ARB, 1997d; HEI, 1995).

In the last decade, results of inhalation bioassays of rodents have demonstrated the carcinogenicity of diesel exhaust. Seven studies in rats exposed to greater than 2 milligrams per cubic meter (mg/m^3) of whole diesel exhaust longer than 24 months, reported statistically significant increases in lung tumors (ARB, 1994b; Heinrich, 1995; Nikula, 1995). An exposure of 2.0 mg/m^3 compromises the clearance capacity of the rat lung. Studies of other rodents have been less extensive. The results in mice were mixed, depending on the strain. All three studies in hamsters were negative (ARB, 1997d).

The International Agency for Research on Cancer (IARC) concluded in 1989 that there is sufficient evidence that whole diesel engine exhaust probably causes cancer in humans and classified diesel exhaust in Group 2A: Probable human carcinogen (IARC, 1989a). The National Institute of Occupational Health and Safety recommended that whole diesel exhaust be regarded as a potential occupational carcinogen (NIOSH, 1988). The Office of Environmental Health Hazard Assessment is in the process of evaluating diesel exhaust as a potential toxic air contaminant (ARB, 1997d). The U.S. EPA is currently in the process of developing a health assessment for diesel exhaust; their first draft was released December 1995. The State of California has determined under Proposition 65 that diesel engine exhaust is a carcinogen (CCR, 1996).

Diesel exhaust is currently in the identification phase as a proposed Toxic Air Contaminant under California's air toxics program (AB 1807). The first draft report was released in June 1994 for a six month comment period. A workshop was held in September 1994 to discuss the draft report. To further our understanding of the human health effects of diesel exhaust, the Office of Environmental Health Hazard Assessment, Health Effects Institute, World Health Organization, National Institute of Occupational Safety and Health, United States Environmental Protection Agency, and the ARB sponsored a scientific workshop to discuss the use of epidemiological data in developing quantitative cancer risk estimates for diesel exhaust. The workshop was held on January 29-30, 1996 in San Francisco.